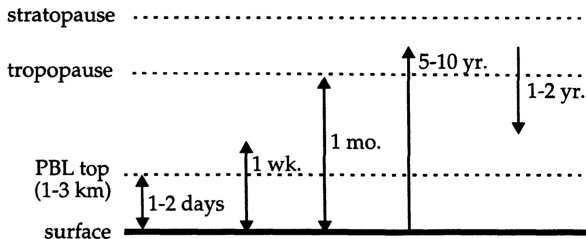


The Atmosphere

Composition and Structure



Outline of Topics

- 1 Intro to Air Pollution
- 2 Atmospheric Composition
 - Concentration of Gases
 - Particulate Matter
- 3 Structure of the Atmosphere
 - Thermal Stratification
 - Mixing Times
 - Spatial Variability of Composition
- 4 Light
 - Nature of Light
 - Sunlight

What are the major problems due to pollutants discharged into the atmosphere?

- Stratospheric ozone depletion (due to CFCs, HCFCs, etc)
- Global climate change (due to GHGs, etc)
- Acid deposition (SO_2 , NO_x)
- Smog (VOCs, NO_x)
- Particulates (PM, especially 'fine PM')
- Other toxic air pollutants (eg, CO, Pb, Hg, PAHs and other toxic organics, etc)

Lecture Question

What are the *criteria pollutants*? And what the heck IS a 'criteria pollutant', anyway?

- Carbon monoxide, CO
- Nitrogen dioxide, NO₂
- Ozone, O₃
- Lead, Pb
- Particulates, PM₁₀ and PM_{2.5}
- Sulfur dioxide, SO₂

Lecture Question

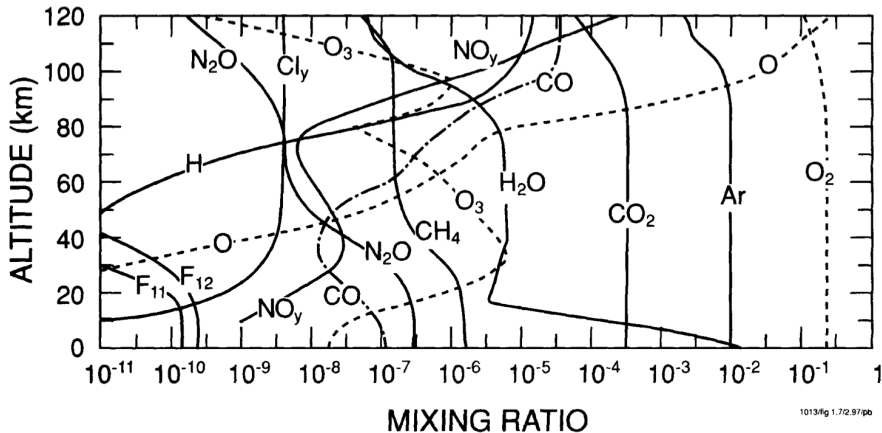
What is in “air?” What is it made of?

The five main gases, with their concentrations, are:

1. Nitrogen, N_2 : 78.080%
2. Oxygen, O_2 : 20.95%
3. Water vapor, H_2O : $\sim 2.5\%$ (variable, up to 4%)
4. Argon, Ar: 0.93%
5. Carbon dioxide, CO_2 : 0.04% (398.78 ppm 12/2014 avg at NOAA Mauna Loa observatory)

Vertical Concentration Profiles

Does the composition of air stay the same as the altitude changes?



1013/fig 1.72.97/pb

Relative and Absolute Concentration Units

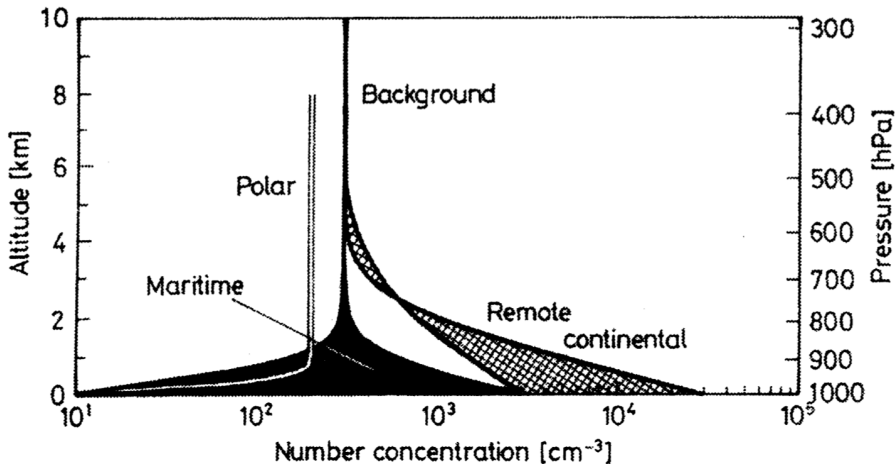
What a minute: the concentration of O₂ in air looks constant (~ 20%) to an altitude of about 80 km. So why is it hard to breathe on top of Mt. Everest (7.5 km altitude)?

altitude, km	pressure, atm	integrated mass %
0	1.000	0.00 %
10	0.287	71.35 %
15	0.153	84.66 %
25	0.044	95.61 %
50	0.002	99.81 %
100	0.000	100.00 %

Note: diameter of the earth is 6400 km.

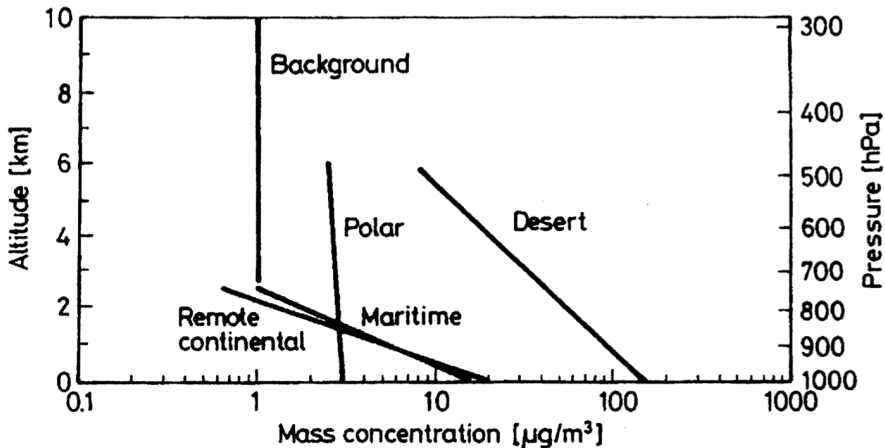
Particulate Matter

We've talked about gases; how much *particulate matter* (PM) is there in the atmosphere? And why should we care?



Particulate Matter

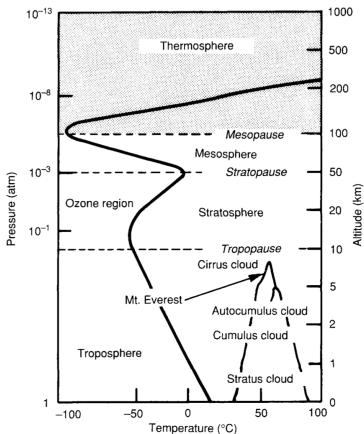
We've talked about gases; how much *particulate matter* (PM) is there in the atmosphere? And why should we care?



Structure of the Atmosphere

Lecture Question

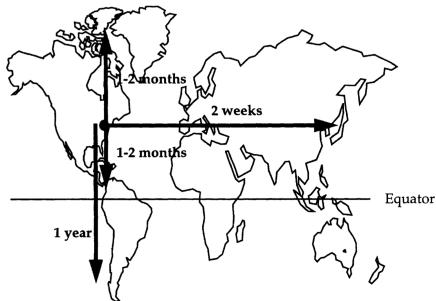
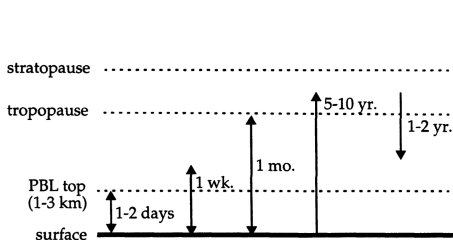
What are the main regions (layers) of the atmosphere? Why do these layers form?



- **Troposphere:** 0–15 km
Lower 1–3 km is the *planetary boundary layer* (PBL.)
- **Stratosphere:** 15–50 km
- **Mesosphere:** 50–100 km
- **Thermosphere:** 100+ km

Time Scales of Atmospheric Mixing

How long does it take for air to mix?



Spatial Variability of Composition

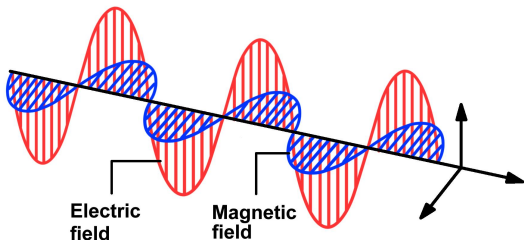
So why are mixing rates important?

- An important factor in determining the *spatial variability* of atmospheric composition.
- Atmospheric removal rate of a given substance are mainly determined by three properties.
Chemicals that do not absorb sunlight, are not reactive, and are not soluble will tend to have long atmospheric lifetimes.
- Mixing vs removal determines spatial scale of the effects of a given pollutant.

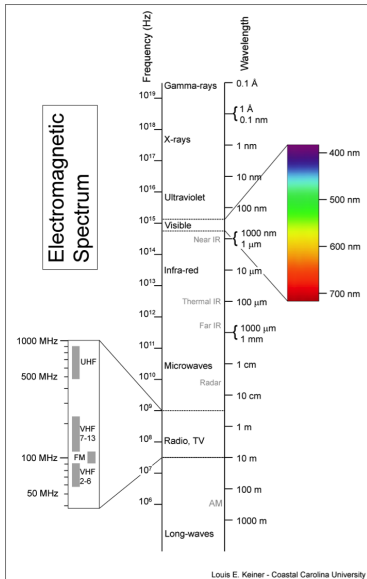
Light as Electromagnetic Radiation

Lecture Question

How does light act like a wave? What is the mathematical relationship between wavelength, frequency, and speed of propagation?



The Electromagnetic Spectrum



Lecture Question

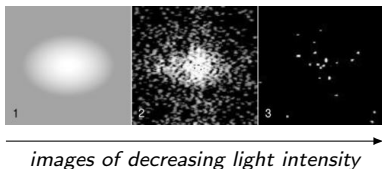
What wavelengths correspond to the ultraviolet and visible regions of the EM spectrum?

Wavelengths EM Region

< 10 pm	gamma ray
10 pm – 10 nm	x-ray (“hard” and “soft”)
10 – 200 nm	vacuum ultraviolet
200 – 380 nm	near ultraviolet
380 – 750 nm	visible
0.75 – 1.4 μm	near infrared
1.4 – 3 μm	short-wave infrared
3 – 8 μm	mid-wave infrared
8 – 15 μm	long-wave infrared
15 – 1000 μm	far infrared
1 mm – 1 cm	microwave
1 cm – 10 m	radiofrequency

Lecture Question

How does light behave as a particle? What is the relationship between energy and wavelength?



- Light imparts energy *in quantized amounts*

$$E = h\nu = \frac{hc}{\lambda}$$

- Photon energy *increases* as frequency *increases* and wavelengths get *shorter*

Incident Sunlight

Lecture Question

What fraction of sunlight is in the UV, visible, and infrared regions of the spectrum?

